MODIS DATA STUDY
TEAM PRESENTATION

March 30, 1990

AGENDA

1. Simulation of Global Ocean Coverage by MODIS-T (Gregg, Riggs)
2. Updated Estimate of MODIS Command and Data Upload Requirements (McKay)
3. Stability of the Sizing Estimates (Ardanuy)
4. Sizing of Total Ozone, Cloud, Stability, and Precipitable Water Algorithms (Andrews, Hoyt)
5. Level-2 to Level-3 Sea-Surface Temperatures Sizing (Wolford)

SIMULATION OF GLOBAL OCEAN COVERAGE BY MODIS-T

Having addressed the question: what is the land coverage under ocean priority, we now turn to the converse question: what will the ocean coverage be if, for any scan containing land, the entire scan is in land mode? This simulation was run at a tilt of +50° in anticipation of maximizing bi-directional reflectance. Thus, at a +50° tilt, if any area under the scan contained land, the entire scan was considered land.

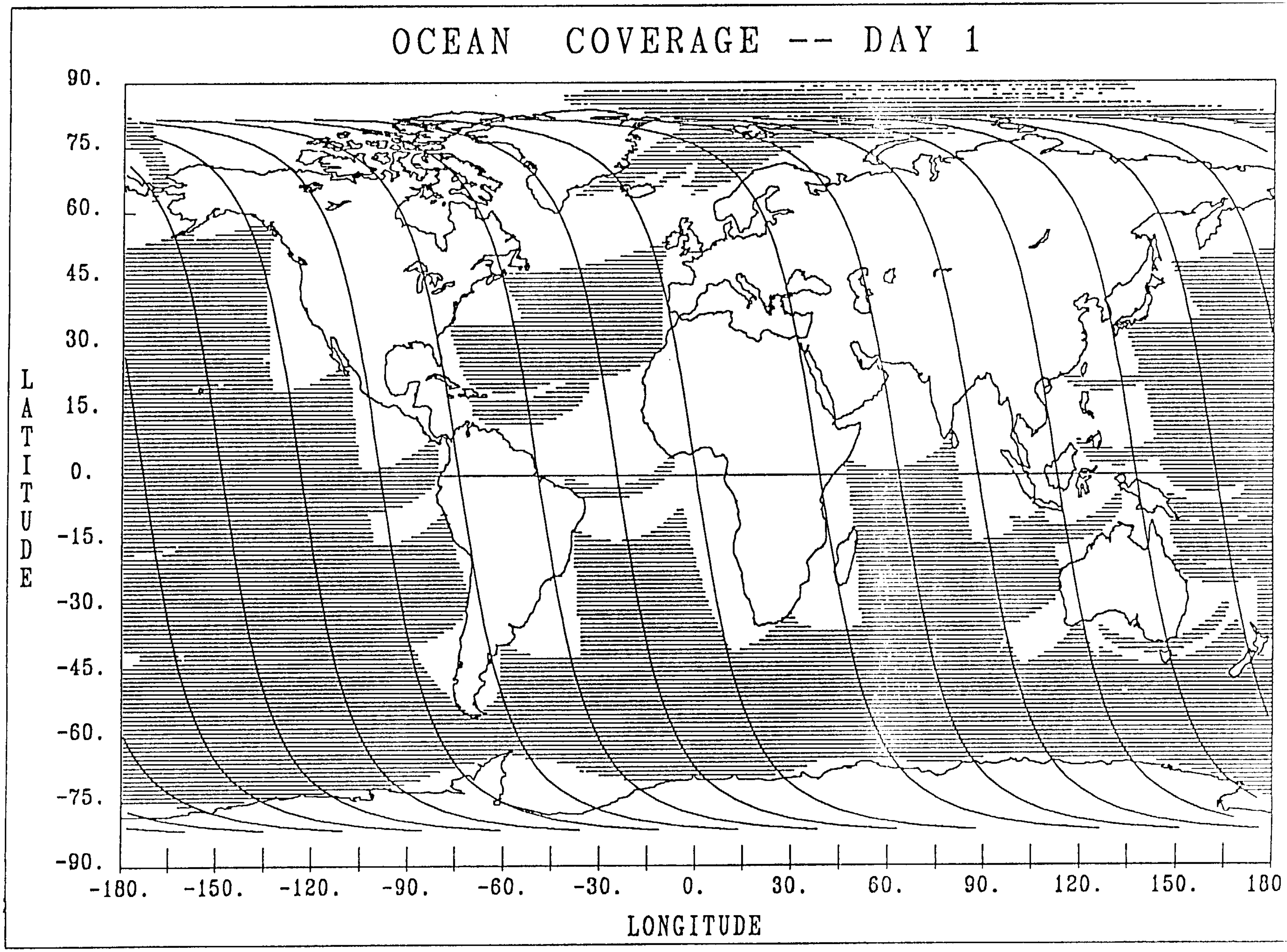
The resulting ocean coverage is depicted in Fig. 1 for a single day. First, it should be noted that the scan coverage is much greater than under the 0° and 20° tilts shown before, nearly extending to the previous and successive sub-satellite ground track at the Equator.

A full 16 day simulation (Fig. 2) revealed substantial ocean coverage, despite land priority. At a computed ocean area by the GVDS of 3.58×10^8 km^2, 3.17×10^8 km^2 was covered, or 88.6%.

Note the lack of coverage of the North Atlantic, Arabian Sea, and Bay of Bengal, and the sparse coverage of the Gulf of Mexico.

However, it is important to note that the ocean coverage is exaggerated by the 50° tilt. This tilt is likely too extreme for most ocean applications since it produces a large atmospheric path length that will reduce the effectiveness of the atmospheric corrections. A smaller tilt will result in much less ocean coverage.

Secondly, as with land coverage under ocean priority, coastal areas are covered exclusively by scan edges. Unlike the previous case, this is an extremely disadvantageous result since the atmospheric path length is very large. We estimated a spacecraft zenith angle of over 80° at the scan edge. Thus useable coastal ocean coverage under this scenario is likely to be much reduced than one might expect given the results of Fig. 2.


OCEAN COVERAGE -- DAY 1
90.
75.
60.
45.
30.
15.
0.
-15.
-30.
-45.
-60.
-75.
-90.
LATITUDE
-180.
-150.
-120.
-90.
-60.
-30.
0.
30.
60.
90.
120.
150.
180.
LONGITUDE

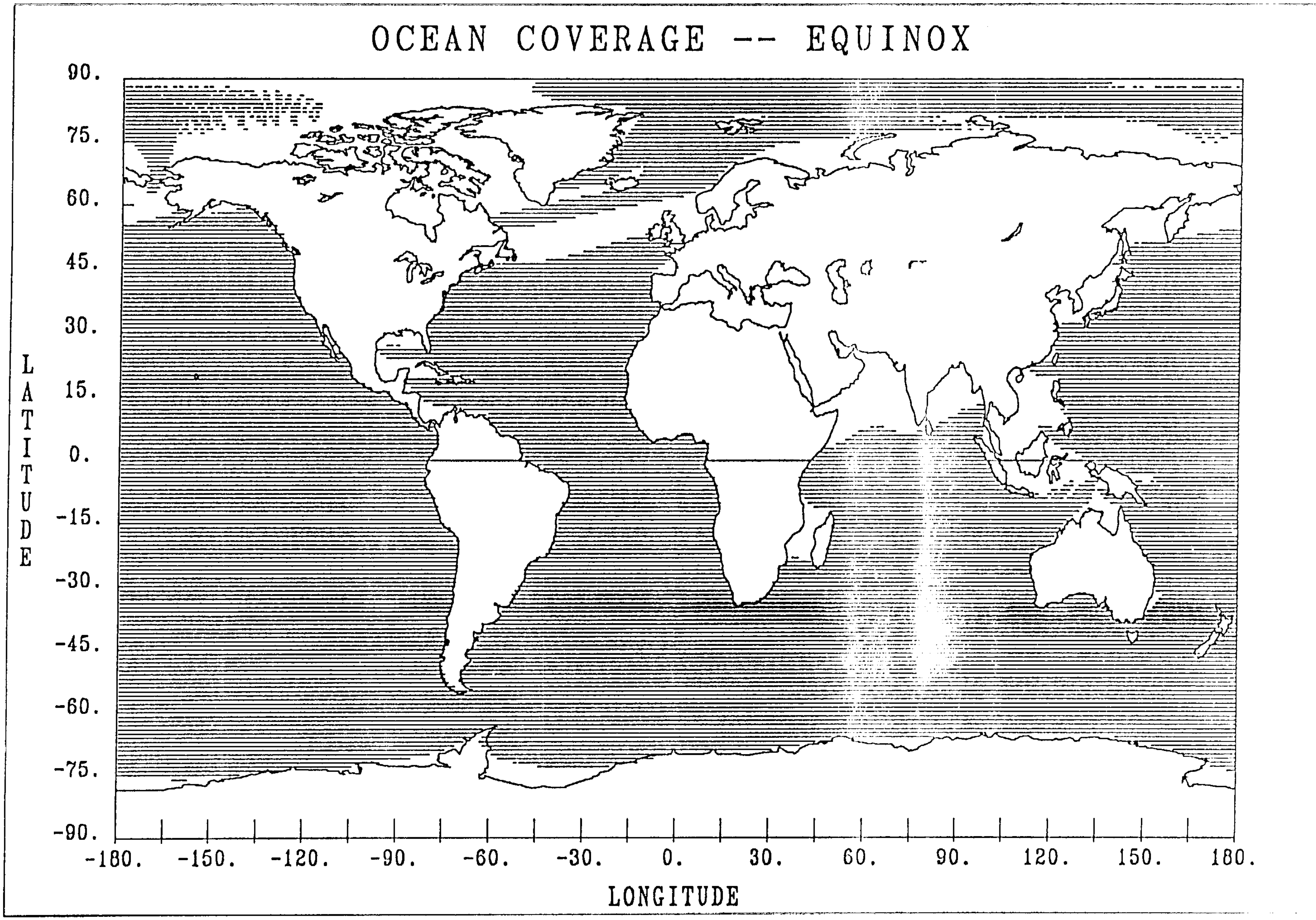

OCEAN COVERAGE -- EQUINOX
LATITUDE
90.
75.
60.
45.
30.
15.
0.
-15.
-30.
-45.
-60.
-75.
-90.
-180.
-150.
-120.
-90.
-60.
-30.
0.
30.
60.
90.
120.
150.
180.
LONGITUDE

Fig 22

Updated Estimate of MODIS Command and Data Upload Requirements

Since the last estimate of data uplink requirements for the MODIS instruments was prepared early in the MODIS data study effort, a number of requirements included in the earlier estimate have been more precisely defined. Since the MODIS data study team is dealing with several issues that potentiall affect data uplink requirements, this seems like an opportune time to reexamine overall MODIS requirement estimates. This is true even though many of the specifics relating to MODIS instrument operation continue under study by the instrument manufacturers, and uplink allocations for many items must still be based on assumed MODIS instrument operational capabilities not verified by the potential instrument manufacturers.

For this data volume estimate it is assumed that the instrument processing circuitry can recognize and process the following commands:

Instrument Operation

Power On/Off [Time, Power On], [Time, Power Off], ..., [Time, Power On], [Time, Power Off]

Safing Secure/Release [Time, Secure], [Time, Release], ..., [Time, Secure], [Time, Release]

Scan On/Off [Time, Scan On], [Time, Scan Off], ..., [Time, Scan On], [Time, Scan Off]

Day/Night mode [Time, Day], [Time, Night], ..., [Time, Day], [Time, Night]

Land/Ocean mode [Time, Land], [Time, Ocean], ...,[Time, Land], [Time, Ocean]

MODIS-T tilt [Time, Angle], [Time, Angle], ...,[Time, Angle]

Miscellaneous housekeeping Instrument control items unique to the specific instrument designs

Instrument Calibration

Calibration lamps [Time, On], [Time, Off]

Lamp monitor detectors [Time, On], [Time, Off]

Spectral calibrator [Time, Initiate]

Blackbody temperature [Time, Fixed Temperature 1], [Time, Fixed Temperature 2, ...,[Time, Floating Temperature]

Solar diffuser plate [Time, Deploy], [Time, Store]

Active cavity radiometer [Time, On], [Time, Off]

Yaw-pitch maneuver [Time, On], [Time, Off] (occasional use only)

Moon calibration [Time, On], [Time, Off] (monthly use only)

Electonics self-check [Time, Initiate]

Direct Broadcast

High-gain broadcast [Time, On], [Time, Off]

"Omni" Band select [Time, Band Selection 1, Band Selection 2, ..., Band Selection n], ..., [Time, Band Selection 1, Band Selection 2, ..., Band Selection n]

Calibration constants and other-instrument data

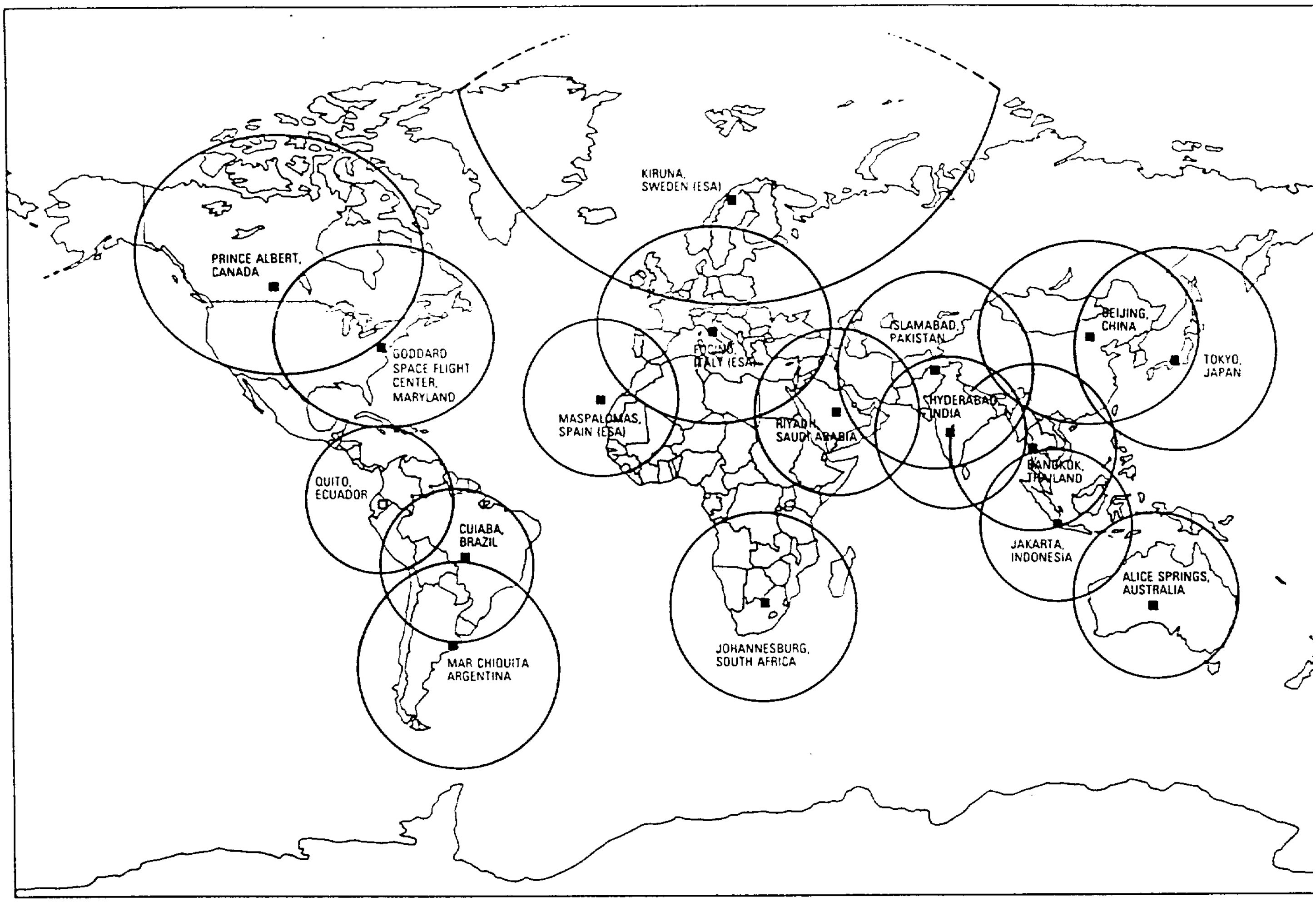
Software select

Software uploads (occasional use only)

Direct broadcast capability (direct data transmission from the orbiting platform to the data user) is considered probable for the EOS mission but most of the operational specifics for this service are not yet defined. In this analysis, it is assumed that the high-gain direct broadcast mode can handle the entire real-time data stream generated by the EOS instruments including all MODIS data. It is further assumed that high-gain direct broadcast of MODIS data will be activated only when the platform is within the coverage region of a landsat type antenna known to be actively receiving EOS data. It will be assumed that the "omni" direct broadcast capability serves the needs of many users in densely populated areas and is also adaptable to serve the special needs of isolated investigators in remote regions of the earth including those doing field experiments or in situ measurements. This is equivalent to assuming that the "omni" direct broadcast service must be adaptable to the needs of a wide spectrum of users. Note that none of the direct broadcast capabilities and requirements

LANDSAT 4/5 COVERAGE

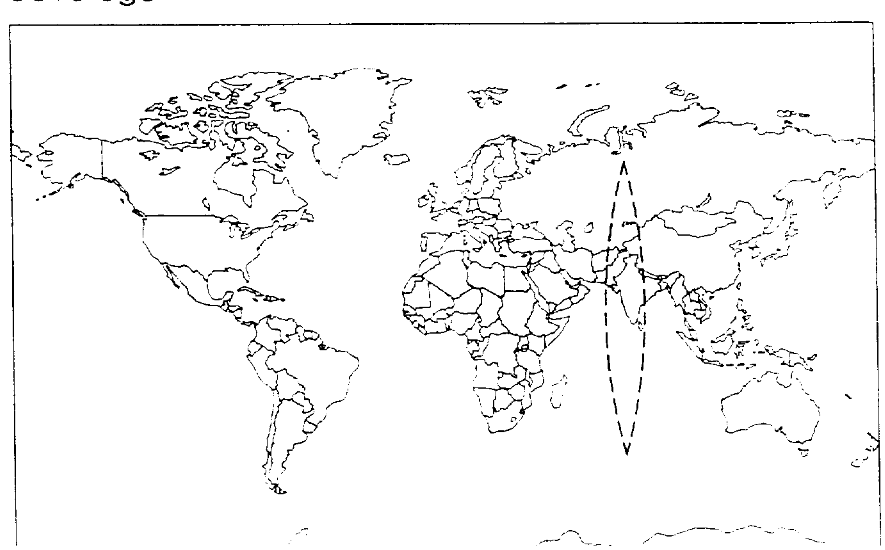
LEGEND: ■ Receiving Stations In Operation □ Receiving Stations Planned



TDRSS COVERAGE WORLDWIDE

COVERAGE WITH 2 SPACECRAFT (TDRSS East & West)

LEGEND: Zone of no TDRSS Coverage



implicit in the above list has been specifically endorsed by those organizational entities responsible for defining EOS direct broadcast operation.

Assuming a command structure as given in the list, command frequencies have been estimated, and an overall data upload requirement for the MODIS instruments has been obtained as in TABLE 1. Since the estimate is being prepared for a representative day with no special instrument requirements, several occasional or controversial items were excluded in the tally. This is notably true for direct broadcast of calibration constants and other instrument data, for remote selection of on-board processing routines, and for on-board processing software uploads. All of these items are of controversial existence.

	Estimated Bytes/command	Estimated Commands/day MODIS-N	Estimated Commands/day MODIS-T	Daily Req'mt Bytes
		Instrument Operation		
Power On/Off	9	0	0	0
Safing Secure/Release	9	0	0	0
Scan On/Off	9	0	0	0
Day/Night mode	9	30	30	540
Land/Ocean mode	9	82	82	1476
MODIS-T tilt	12	0	58	696
		Instrument Calibration		
				0
Calibration lamps	9	2	1	27
Lamp monitor detectors	9	2	1	27
Spectral calibrator	9	1	1	18
Blackbody temperature	12	3	0	36
Solar diffuser plate	9	2	1	27
Active cavity radiometer	9	2	1	27
Yaw-pitch maneuver	9	0	0	0
Moon calibration	9	0	0	0
Electronics self-check	9	1	1	18
				0
		Direct Broadcast		
High-gain broadcast	9	30	30	540
"Omni" band select	20	30	30	1200
Calibration constants	?			
Software select	?			
Software uploads	?			
TOTAL		185	236	4632

STABILITY OF THE SIZING ESTIMATES

In December 1988, the MODIS Data Study Team presented a preliminary evaluation of the EOS CDHF performance required to generate the data products proposed by the MODIS Science Team Members. Since then, the composition of the science team has altered, and the team's concepts of the MODIS data products have matured significantly.

The estimates, presented in the "MODIS Information, Data, and Control System (MIDACS) System Specifications and Conceptual Design," (NASA TM 100721) explicitly sized three products:

- vegetative index (7.5 MFLOPS), provided by C. Justice
- chlorophyll (0.2 MFLOPS), provided by W. Esaias
- OLR/cloud properties (94 MFLOPS at full resolution or 6 MFLOPS at 5 km resolution), provided by J. Susskind

Based on these explicit detailed treatments, a methodology was employed to obtain overall processing estimates. The set of proposed data products were divided into three algorithm types:

- Type 1: Land product algorithms employing a simple function of radiances, but a sophisticated mapping scheme.
- Type 2: Atmospheric retrieval algorithms requiring iterative mathematical operations and radiative transfer calculations.
- Type 3: Ocean biological activity algorithms employing a "relatively simple" atmospheric correction and using a simple functional combination of radiances.

The results indicated a performance requirement of between 408 and 3048 MFLOPS to process 24 hours of data, depending on whether the type-2 products were generated at 2-k or 5-km resolution. By accounting for reprocessing (at twice the data rate), near-real-time processing, special processing, browse processing, maintenance, and processor utilization, a final requirement of 16 GFLOPS was estimated (or 2 GFLOPS if 5-km is assumed).

We are now explicitly sizing each proposed scientific algorithm, and the set of utility algorithms. Several investigators employing the most computationally demanding algorithms (e.g., Paul Menzel and Mike King) are considering their application at a subsampled 5-km resolution. The final numbers are still being compiled; reassuringly, it appears that the sizing estimates are quite consistenT with the first-order estimates made over a year ago.

SIZING OF TOTAL OZONE, CLOUD, STABILITY, AND PRECIPITABLE WATER ALGORITHMS

1. Sizing of CO2 Slicing Algorithm

Dr. P. Menzel has proposed using the CO_2 slicing algorithm to generate three of the core MODIS cloud products:

- Cloud Effective Emissivity
- Cloud Top Height
- Cloud Top Temperature

This technique will use MODIS-N channels 33 to 36 (the CO_2 channels) and will be used both day and night.

The algorithm determines the cloud-top temperature and the effective emissivity. Atmospheric profiles are required as input to the processing. (At this time, it is not clear what the source of the required profiles will be.) The processing also requires the clear sky radiance, i.e., the values expected if there are no clouds.

The cloud top pressure is determined from the ratio of the difference between the observed and clear sky radiance in two channels. This ratio is calculable from the integrals of the radiative transfer function to the surface and the cloud height.

The integration requires both that the fractional transmittance and the Planck function be known as a function of frequency. The cloud-top pressure is adjusted in the integral and that value of the pressure which produces the best match to the difference ratio is the cloud-top pressure.

The cloud-top height is this pressure, i.e., the height will be expressed as mb. The temperature is determined from the pressure and the profiles. After the height/pressure is determined, the effective emissivity is calculated from the ratio of observed minus clear radiance to that expected for opaque clouds.

Multiple ratios are used to determine multiple pressures and effective cloud amount. The values which produce the best match to observations are selected as the "correct" value.

This is a computationally intensive algorithm since the radiative transfer calculation is done. The current algorithm uses 21 pressure intervals. In sizing the algorithm, the assumption is made that the calculation is done for all levels (the integral is actually done from the ground up and the calculation stops when the cloud top temperature is reached). Hence, this estimate is an upper limit. (As few as 10 layers out of 21 might enter into the integration.)

The use of four CO_2 channels to calculate four ratios and determine the three products requires approximately 18,000 FLOP per location.

This number was obtained by analyzing the code provided by Dr. Menzel.

The consensus of the atmospheric working group at the February team meeting was that this product will also be generated once for each 25 km^2 area. Either a single pixel will be selected or an average taken of a few pixels. This is necessary to reduce the load on the CDHF. (It should be noted that both this algorithm and the King technique will be applied at full resolution and coverage as part of special studies.)

It is possible to use a single equation to estimate the processing requirement. The result is:

$$P = \{ \# * \% * 18{,}000 \}/A$$

where: # = number of fields of view per second
% = fraction of pixels with cloud cover
A = number of pixels in the resolution cell

If the assumption is made that %=0.5 and with #=12,000 and A=25, then P= 4.3 MFLOPS. This processing will be done both day and night. With a scan period of about 1.02 sec., this also implies that **4.3 MFLOP are required per (~~daytime~~) scan.**

2. Atmospheric soundings: Total Precipitable Water, Stability, and Total Ozone

Dr. Paul Menzel has proposed to use the MODIS thermal channels to make soundings similar to the HIRS/MSU soundings now made on the McIDAS system at the University of Wisconsin. The output of these soundings include temperature and humidity profiles, geopotential heights, a lifted index, total ozone, and an estimate of outgoing longwave radiation. To estimate the CPU requirements for MODIS, Mr. Harold Woolf in Madison was contacted to provide some timing estimates for this algorithm.

For 500 soundings using 20 HIRS wavelengths and 4 MSU wavelengths, 30 minutes of CPU time are required on an IBM PS/2 running at 70 MHz. From the Linpack tables of machine speeds, we estimate that this machine would have a rating of about 0.5 MFLOPS. These numbers imply that 1.8 million floating point operations per sounding are required.

For the same 500 soundings on an IBM 4381, 10 minutes of CPU time are required. This machine is rated at 1.3 Mflops, so the estimated operations per sounding is 1.6 million.

Because MODIS does not have as many thermal channels as HIRS, the above estimate for the number of operations per pixel may represent a slight overestimate. If one pixel out of every 25 is chosen for a sounding (5 km. resolution), 496 soundings per second will be made. This implies a machine capable of performing continually at 843 MFLOPS will be required for this algorithm. There will be about 505 soundings per scan, so there will be about 860 Mflop per scan. If more then one sounding is made in each 5 km. area, then this computational estimate could increase significantly.

A copy of a description of the algorithm is attached. The FORTRAN code is also available.

The conclusion to be reached here is that this algorithm is one of the primary drivers of the sizing of the performance requirements for the core data product processing. Due to the importance of this requirement, the sizing of this algorithm will be confirmed based upon the explicit analysis of FORTRAN code provided by Dr. Menzel.

INTERNATIONAL TOVS PROCESSING PACKAGE (ITPP) SOFTWARE DESCRIPTION AND INSTALLATION GUIDE

Version 4.0, July 1989

This document describes, in brief outline form, procedures for establishing a local/regional system for processing TOVS (HIRS+MSU) sounding data from the TIROS-N/NOAA series of polar-orbiting spacecraft, using the software in part 1 of this tape, and the supporting data contained in subsequent files on this tape (parts 2 and 3).

The algorithms and data-processing techniques were originally developed for 'McIDAS' (Man-computer Interactive Data Access System) at the Space Science and Engineering Center of the University of Wisconsin in Madison (UW/SSEC). Initially based on the Harris 'Slash-6' mini-computer, McIDAS is currently implemented on the IBM 4381 at the SSEC. The original 'export' software was configured for an IBM-OS system to provide the most reasonable portability, given the resources available to those responsible for its maintenance. The package contained in this tape has been modified to expedite its implementation on a VAX system.

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Questions and/or comments concerning the system and its implementation, especially in regard to possible errors, should be addressed to

Mr. Harold M. Woolf
UW/SSEC/CIMSS
1225 West Dayton Street, second floor
Madison, Wisconsin 53706
Telephone ... (608) 264-5325
Twx/telex ... 256-452-UOFWISC MDS

Contents of the remaining files in this portion of the tape
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File 2. Low-resolution (60 naut.Mi.) global topography
File 3. High-resolution (10 naut.Mi.) topography bit map, Nor.Hem.
File 4. High-resolution (10 naut.Mi.) topography heights, Nor.Hem.
File 5. High-resolution (10 naut.Mi.) topography bit map, Sou.Hem.
File 6. High-resolution (10 naut.Mi.) topography heights, Sou.Hem.

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Notes on FORTRAN source (part 1)

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Each routine is now in a separate file on the tape. This is a major departure from previous releases, in which all main programs were in one file, all subroutines in one file, and all functions in another. The new structure should simplify installation and/or updating of routines.

Observe that in most routines in which a file is opened, the 'OPEN' statement is not employed directly; rather, a call is made to subroutine 'OPEND'. This artifice has been employed as part of a major restruct uring of the ITPP software at CIMSS, in which the original IBM version has been upgraded to FORTRAN-77 in order to achieve more compatibility with the 'domestic' TOVS software and the VAX ITPP, both of which were already in FORTRAN-77. While there are still some differences at the main-program level, it has been possible, through this change, to establish a single version for many routines. The user may replace these calls with explicit 'OPEN' statements if desired.

The first card of each main program has the form
PROGRAM XXXXXX

Each main program and subprogram contains a comment card of the form
C **** VERSION OF DD.MM.YY (DAY.MONTH.YEAR)

Users for whom this is not the first package supplied will find the 'version-dates' an indispensable means of determining which routines have been changed since their initial implementation. Although in the past updates to the package have been provided in the form of selected software and coefficients, the most recent changes are too extensive, and the number of users world-wide too great, to permit such 'limited-edition' updating. Therefore, updates - to sofware, coefficients, or both - are in the form of a new total-package tape. It is left to individual users to determine which 'new items' are relevant.

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Notes on supporting-data files
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A new high-resolution (10 naut.mi.) topography scheme has been implemented that requires only one-fourth the disk space of the original. The standard package contains complete datasets for both northern and southern hemispheres (see note below regarding installation).

Coefficient/parameter files for the ITPP (part 3) will be found following the topography files.

For each satellite in the series, there is a set of ten files as defined below. The current tape is valid for TIROS-N through NOAA-11 (seven spacecraft), and thus contains 70 coefficient files in addition to the basic files noted above. A double E-O-F terminates the tape. Note that the following file numbers are relative within each group.

File 1. Orbital elements
File 2. Ingest parameters
File 3. Coefficients for HIRS radiative-transfer computations
File 4. Coefficients for MSU (nadir) radiative-transfer comp
File 5. Coefficients for MSU (slant) radiative-transfer comp
File 6. Coefficients for HIRS limb-correction
File 7. Coefficients for MSU limb-correction
File 8. Synthetic coefficients for physical retrieval
File 9. Synthetic coefficients for statistical retrieval
File 10. Radiative-transfer tuning coefficients

The coefficients in files 2 through 10 are determined initially for each satellite, and can be considered fixed for its operational lifetime unless major changes occur in the performance of one or more spectral channels.* Orbital elements in file 1 (updated weekly) are needed for navigation (earth-location) of real-time data obtained via direct read-out of the spacecraft (VHF or HRPT). The elements included on this tape are provided to assist in initial implementation of the system; users must make their own arrangements for continued acquisition of that information for real-time applications.

*Occasionally, some of the MSU calibration quality-control limits in file 2 may need to be adjusted to avoid discarding good data as a result of changes in gain or other instrument characteristics. Programs 'XMSUIP' and 'UMSUIP' are provided to permit examination and modification, respectively, of those parameters.

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Constructing the TOVS data-processing system
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The system makes extensive use of unformatted, direct-access disk files for efficiency in I/O operations. To assist in establishing the permanent data files (orbital elements, coefficients, and topography), software has been provided to read the data from ASCII files extracted from the tape, and write to binary disk files.

Program	Tape File	ASCII file(s)	Binary file(s)
TOPOGF	2+	TOPOLRES.ASC	TOPOLRES.DAT
TOPOGH++	3+	BMAPTOPN.ASC	BMAPTOPN.DAT
	4+	HRESTOPN.ASC	HRESTOPN.DAT
	5+	BMAPTOPS.ASC	BMAPTOPS.DAT
	6+	HRESTOPS.ASC	HRESTOPS.DAT
PUTELE	1*	ORBELNXX.ASC	ORBELNXX.DAT (XX=05,06,...)
INGPAR	2	INGEPAXX.ASC	INGEPARM.DAT
HIRTCF	3	HIRTCOXX.ASC	HIRTCOEF.DAT
MSUTCF	4	MSUTCOXX.ASC	MSUTCOEF.DAT
MSZTCF	5	MSZTCOXX.ASC	MSZTCOEF.DAT
HIRLCF	6	HIRLCOXX.ASC	HIRLCOEF.DAT
MSULCF	7	MSULCOXX.ASC	MSULCOEF.DAT
RTVCFS	8	RTVSCOXX.ASC	RTVSCOEF.DAT
RTVCFL	9	RTVLCOXX.ASC	RTVLCOEF.DAT
TUNECF	10	TUNECOXX.ASC	TUNECOEF.DAT

Notes:
+ In the basic group (first six files in part 2 of the tape)
++ If global topography is not required, the user should establish only the hemisphere he needs, and in subroutine 'NTOPO' of program 'TOVRET' replace the call to subroutine 'HRTOPO' with a direct call to 'HRTOPN' (northern hemisphere) or 'HRTOPS' (southern hemisphere).
* Within a satellite-specific group

Nearly all of the software provided in part 1 is for processing HIRS and MSU data to obtain profiles of atmospheric temperature, humidity, geopotential height, and geostrophic wind, and for displaying and manipulating those profiles in various ways. Essential operations are 'ingest', 'preprocessing', and 'retrieval'. The term 'RTC' stands for radiative-transfer coefficients, and 'LCC' stands for limb-correction coefficients. Where input parameters are required, programs prompt for keyboard input in the interactive mode of execution. If batch operation is desired, the user must make the necessary changes.

RAOHIR and RAOMSU (second and third from last FORTRAN-source files) are supplied to demonstrate the procedures for calculating, from radiosonde temperature and humidity profiles, HIRS radiances and brightness (equivalent-blackbody) temperatures, and MSU antenna or brightness temperatures, respectively.

Ingest
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Function: produce calibrated, earth-located HIRS and MSU radiometric measurements from TOVS 'TIP' data. Two versions are provided; the essential difference is in the type of input data they are designed to handle - either archival ('level 1-b') or direct-readout (realtime).

Program	Input(s)	Output(s) ( ) = LUN
*******	********	*********
ORBITS	*orb-elem(11) prompts	printout of subsatellite tracks for spacecraft, space and time windows obtained from prompts

* Updated by program 'PUTELE' with data obtained from Direct Readout User Services.

Level 1-b: data that has been through preliminary processing by NESDIS operations' TOVS ground system, and is provided on standard computer tape to users, upon request, by the Satellite Data Services Branch of NESDIS. Such tape contains, in addition to values (in digital counts) representing radiometric measurements, earth-location information and calibration parameters required to transform the raw data values into radiance or brightness temperature. Three programs are supplied for this type of operation:

Program	Input(s)	Output(s) ( ) - LUN
*******	********	*********
INVTAP	1-b tape(10) *prompts	printout of data type, times, and locations for each file
TOVTAP	1-b tape(10) **prompts	selected HIRS(11) and MSU(12) data on disk; printout of relevant information
TOVING	HIRS disk(11) MSU disk(12) HIRS RTC(13) ***prompts	calibrated, located data on disk(20); printout

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Structure of the 'TOVSINGO' file (output of INGTOV/TOVING)

****

```
      access method: FORTRAN direct-access I/O
      record length = 112 INTEGER*4 words

Record 1: HIRS header
      WORD(S)    CONTENT
      -------    -------
         1       NOAA satellite number
         2       number of records following that contain data (NRECH)
         3       direction (1 = ascending, -1 = descending)
         4       start time (seconds x 64)
         5       start date (YYDDD)
         6       end time (seconds x 64)
         7       end date (YYDDD)
         8       calibration (1 = occurred at least once)
         9       logical sum of errors encountered
        10       spare (0)
        11       number of records read from input file
        12       number of undefined/unrecognized encoder positions
        13       start time (milliseconds)
    14-112       spare (0)
```

Organization of HIRS data in records 2 through NRECH+1:

Each record contains data for 4 individual fields of view (IFOVs). The last such record may not be full; unused locations are zero-filled. Brightness temperatures are deg x 100.

```
   IFOV sub-record (28 words):
      WORD(S)    CONTENT
      -------    -------
         1       line*65536+spot (i.e., two 16-bit quantities)
      2-20       brightness temperatures, channels 1 through 19
        21       channel 20 (visible) radiance (mw/m**2-sr-cm**-1)
        22       latitude (0-90, deg x 100, +N,-S)
        23       longitude (0-180, deg x 100, +E,-W)
        24       local zenith angle (deg x 100)
        25       flag - see below for meaning of specific bits
        26       date (YYDDD)
        27       time (seconds x 64)
        28       spare (0)
```

Consider the flag (word 25) as an array of 32 bits, with the most-significant designated 1, and the least-significant designated 32. If bit 25, 27, or 32 -- or any combination thereof -- is non-zero, the data in that IFOV should not be used. Other bits may be turned on (1) from time to time, but the conditions they denote do not affect the usability of the data.

If NRECH is less than 1400, all records from NRECH+2 through 1401 are zero-filled.

```
Record 1402: MSU header
      WORD(S)    CONTENT
      -------    -------
         1       NOAA satellite number
         2       number of records following that contain data (NRECM)
         3       direction (1 = ascending, -1 = descending)
         4       start time (seconds x 64)
         5       start date (YYDDD)
         6       end time (seconds x 64)
         7       end date (YYDDD)
         8       spare (1)
         9       spare (0)
        10       number of records read from input file
    11-112       spare (0)
```

Organization of MSU data in records 1403 through NRECM+1402:

Each record contains data for an entire scan line of 11 IFOVs, with 10 words used for each and the last two words of the record zero-filled. Units and sign conventions are the same as for HIRS.

```
   IFOV sub-record (10 words):
      WORD(S)    CONTENT
      -------    -------
         1       line*65536+spot
         2       date
         3       time
         4       latitude
         5       longitude
         6       spare (0)
      7-10       antenna temperatures, channels 1 through 4
```

****

Structure of the 'TOVORB' and 'TOVSND' files (output of TOVPRE)

****

*** TOVORB

access routine: TSNIO

record length = 112 INTEGER*4 words

```
Record 1: header
      WORD(S)    CONTENT
      -------    -------
         1       YYDDD at start of pass
         2       HHMMSS at start of pass
         3       HHMMSS at end of pass
         4       NLINES = number of HIRS lines in pass
         5       NOAA satellite number
         6       spare ... if non-zero, has significance only at CIMSS
         7       direction (1 = ascending, 2 = descending)
        50       start time of pass in milliseconds
        51       HIRS limb-correction flag
```

52	MSU limb-correction flag
53-112	spare (0)

Organization of data in subsequent records:

There are 30 parameters, each of which is allotted 50 records on disk, providing for 100 HIRS scan lines (stored two lines per record). If the 'image' or orbital pass contains less than 100 lines, the unused portion of each 'logical (parameter) file' is filled with 999999 to serve as a 'missing' indicator to software that accesses the file.

The parameters are as follows (all brightness temps are deg x 100):

1	latitude (deg x 100,+N,-S)
2	longitude (deg x 100,+E,-W)
3	solar zenith angle (deg x 100; 9000 if night)
4-22	brightness temperatures, HIRS channels 1 through 19
23	brightness temperature, MSU channel 1a ... see below
24-27	brightness temperature, MSU channels 1 through 4
28	total outgoing longwave flux (watt/sq-meter, x 100)
29	bidirectional reflectance derived from HIRS channel 20(vis)
30	brightness temperature, HIRS channel 18a ... see below

Item 23 ... If MSU data are limb-corrected, this is channel 1 with surface effects retained; if not limb-corrected, this is indexing information and not mappable.

Item 30 ... If daytime, this is channel 18 (4 micron window) with a first-order approximate correction for reflected sunlight.

The access routine 'TSNIO' does the internal calculations to locate the data on disk, given parameter number, initial line, initial element, number of lines, and number of elements.

*** TOVSND

access routine: SNDIO
record length = 112 INTEGER*4 words
first record is 'header', and is identical to that for 'TOVORB'

Organization of data in subsequent records:

Parameters 1 through 28 (see 'TOVORB' description for contents) are stored as a vector with coordinates of line and element (or spot). Thus each 112-word record contains data for four HIRS fields-of-view. The access routine 'SNDIO' does the internal calculations to locate the data on disk, given line and element.

****

Structure of the 'TOVRET' file

****

access routine: RETIO
record length = 112 INTEGER*4 words

Record 1: header

WORD(S)	CONTENT
1-52	same as TOVORB/TOVSND
53-108	spare (0)
109	line-coordinate of last sounding made
110	elem-coordinate of last sounding made
112	number of soundings made = NRET

Records 2 through NRET+1:

All pressures are in units of millibars.
All temperatures are in units of degrees Kelvin x 100.
A value of 999999 denotes 'missing' or 'fill'.

WORD(S)	CONTENT
1	latitude (deg x 100,+N,-S)
2	longitude (deg x 100,+E,-W)
3	time (HHMM)
4	surface elevation (meters above MSL)
5-19	geopotential height (meters)
20	air temperature at ground level (or 1000 mb)
21-34	air temperature at 850, 700, ..., 10 mb
35	dew-point temperature at ground level (or 1000 mb)
36-40	dew-point temperature at 850, 700, ..., 300 mb
41-59	HIRS brightness temperatures, channels 1 - 19
60-63	MSU brightness temperatures, channels 1 - 4
64	surface skin temperature
65	image-line coordinate at center of retrieval box
66	image-element coordinate at center of box
67	pressure at ground level
68-77	first-guess temperature at 1000, 850, ..., 100 mb
78-82	first-guess dew-point at 850, 700, ..., 300 mb
83-90	fill
91	TOTAL-TOTALS stability index (deg x 100)
92-95	fill
96	total ozone (Dobson Units x 100)
97	total precipitable water vapor (mm x 100)
98	total outgoing longwave flux (watt/sq-meter, x 100)
99	cloud pressure
100	cloud temperature
101	fill
102	rtvl type (clear=10, partly-cloudy=20, MW+HS=30)
103	solar zenith angle (deg x 100; 9000 if night)
104-112	winds (DDDFFF: deg,meters/sec)

****

END OF DOCUMENT

****

notes:
* Number of files to read; program terminates on double EOF if encountered before count is satisfied.
** Physical file numbers of HIRS and MSU data, plus beginning and ending times.
*** Satellite number (use 5 for TIROS-N) -- required because information in tape header records is confusing, i.e. TIROS-N is 1; NOAA-6 is 2; 7 is 4; 8 is 6; 9 is 7; 10 is 8.

Direct-readout: data obtained on-site by direct downlink from the spacecraft. The ssec system uses data from the VHF (137MHz) beacon. Such data can also be acquired by extracting 'TIP' from an HRPT datastream; a model of the necessary software is provided as a guide to the user. Processing of direct-readout data is much more complex than that of level 1-b, since the user must do everything - decommutation of raw data, navigation or earth-location, and in-flight calibration. Three programs are supplied:

Program	Input(s)	Output(s)
PRETIP	HRPT file	disk file(9) containing TIP data

Note: the subroutines 'CMHOPN', 'CMHSET', and 'CMHGET', referenced in this program, are not included. The program is supplied to indicate the processing required to extract TIP data from the HRPT stream; software to perform that function is highly installation-dependent and must be provided by the user.

PREING	disk file(9) *prompts	disk file(10) containing decommutated HIRS and MSU data printout
INGTOV	decom data(10) **orb-elem(11) HIRS RTC(13) ing-param(15)	calibrated, located data on disk(20) printout

Notes:
* Year; flag for detailed (diagnostic) MSU printout.
** Updated by program 'PUTELE' with data obtained from Direct Readout User Services.

The data in file 20 will have the same format, regardless of the source and type of ingest. This file serves as input to the next step.

Preprocessor
****

Function: transform calibrated, earth-located HIRS and MSU measurements produced by ingest, into datasets for display and retrieval. The imager (TOVORB), sounder (TOVSND), and retrieval (TOVRET) file names have been structured to permit up to 26 on-line datasets, by incorporating a letter from 'A' to 'Z' into a root. TOVPRE and subsequent programs prompt for a 'file letter' to point to a specific set.

Program	Input(s)	Output(s)
*******	********	*********
TOVPRE	ingest output(20) HIRS RTC(13) HIRS LCC(15) MSU LCC(16) lo-res topog(17) prompts for file, limb-corrn option	imager file(22) sounder file(23) printout
TOVMAP	imager file(22) prompts for file, param(s), start-line	printout of data in (line,element) coordinates
BRITEM	sounder file(23) prompts for file, location	display of all tbb's at one point

Note:

The preprocessor performs the following functions:

If the MSU 'limb-correction' flag is on, MSU data are corrected for
 antenna pattern (transform antenna temp. to brightness temp.);
 limb effects (normalize to theta = 0);
 surface reflectivity (normalize to sfc.emis. = 1);
 liquid water (precipitating cloud) attenuation.

If the HIRS 'limb-correction' flag is on, HIRS data are corrected for limb effects, and water vapor attenuation in the window channels.

In addition, HIRS channels 17 and 18 are corrected, in daylight, for fluorescence and reflected sunlight, respectively, regardless of the state of the limb-correction flag.

MSU and HIRS are colocated by interpolating the MSU observations to the HIRS scan pattern.

Output file 22 has all data for one parameter contiguous on disk, and thus is optimized for imaging;

Output file 23 has all data for one scan spot contiguous on disk, and thus is optimized for sounding.

Programs 'MSUPRO' and 'MSUPLT' perform functions similar to those of TOVPRE and TOVMAP, but for MSU only, which was the data available for major portions of the lifetimes of NOAA-6 and NOAA-8.

Retrieval
****

Function: determine, from preprocessed HIRS and MSU data, vertical profiles of atmospheric temperature, humidity, and geopotential height, as well as total ozone and stability parameters, at high spatial resolution. See note on 'surface data' at the end of this document. There are two very different retrieval programs included in this package: statistical (TOVSTR) and physical (TOVRET).

```
Program        Input(s)          Output(s)
*******        ********          *********
TOVSTR         lo-res topog(17)  retrieval file(24)
               imager file(22)   printout
               sounder file(23)
              *rtvl coef(25)
               prompts for file,
                parameters
```

TOVSTR is a fast statistical retrieval, using the N* procedure to obtain clear-column radiances. It is much less demanding of computer resources than the physical retrieval program, TOVRET. Data provided to this program must have been limb-corrected in TOVPRE.

Note:
* coefficients staged to disk by 'RTVCFL'

```
Program        Input(s)          Output(s)
*******        ********          *********
TOVRET         HIRS RTC(13)      retrieval file(24)
              *MSU RTC(14)       printout
              +HIRS LCC(15)
              +MSU LCC(16)
               lo-res topog(17)
              *MSU RTC(18)
               hi-res topog(27,37)
               imager file(22)
               sounder file(23)
             **rtvl coef(25)
            ***tune coef(30)
           ****prompts for file,
                parameters
```

This program can operate on HIRS and MSU data that have been limb-corrected or not ... the latter seems to give better results.

Notes:
* The RTC in file 14 are for limb-corrected MSU data; those in file 18, for non-limb-corrected data.
+ Needed for regression estimation of first-guess temperature and ozone profiles.
** Coefficients staged to disk by 'RTVCFS'
*** Coefficients staged to disk by 'TUNECF'
**** Specify various options to control execution of program - see source code for parameters and their meanings.

******

TOVRET is our most up-to-date model; it obtains solutions for temperature and water vapor in a single step from combined infrared and microwave measurements.

Program 'MSURET' performs a physical (iterative) retrieval on MSU-only data processed by MSUPRO.

Filtering

****

Function: eliminate soundings of questionable reliability by objective analysis of differences between infrared and microwave retrievals for the same location, and of variability in 1000-500mb thickness and longwave-window vs. Surface temperature.

Program	input(s)	output(s)
FILRET	rtvl file(24) *prompts	rtvl file(24), with 'failed' soundings flagged printout

Note:
* To control filtering parameters ... see source code for details

Enhancement

****

Function: add microwave-only soundings in areas where infrared retrievals were not made, owing to heavy cloudiness, or were flagged 'failed' by the filter program. This program was originally developed when only statistical retrievals could be made (by TOVSTR); if the physical retrieval tovret is used, enhancement should not be needed.

Program	Input(s)	Output(s)
ENHRET	lo-res topog(17) sounder file(23) rtvl file(24) *rtvl coef(25) prompt for file	rtvl file(24)

Note:
* Same coefficients as used with TOVSTR

Geostrophic Winds

****

Function: determine geostrophic winds for 'good' soundings in retrieval file, by least-squares objective analysis of height fields.

Program	Input(s)	Output(s)
WINRET	rtvl file(24) *prompts	rtvl file(24)

Note:
* To control quantity of printout

Redundancy Elimination

****

Function: eliminate redundant infrared retrievals, based on variability in selected HIRS channels.

Program	Input(s)	Output(s)
*******	********	*********
REDRET	rtvl file(24) *prompts	rtvl file(24)

Note:
* For file and to specify other than default control parameters

Retrieval Plotters

****

Function: to plot various quantities from the retrieval file. Input consists of the retrieval file(24) and prompts to control the location and parameters plotted ... See source code for details.

Program	Product
*******	*******
TOVPLF	IR-MW sounding differences, with characters appended to denote results of FILRET and REDRET
TOVPLT	IR-retrieval temperatures

TOVPLF should be run before the next program to be described (COMRET); TOVPLT should be run after file-compression. The latter program may be replicated and/or modified to plot other quantities from the retrieval output.

File Compression

****

Function: compress the retrieval file by deleting soundings that have been flagged by FILRET and/or REDRET, and moving the remaining soundings to replace the 'empty' records.

Program	Input(s)	Output(s)
*******	********	*********
COMRET	rtvl file(24)	rtvl file(24)

******

Note on 'surface data'

Programs ENHRET, TOVRET, and TOVSTR invoke subroutine GETSFX, which is obviously, from inspection of the source code, a dummy routine. The user should provide an interface to actual gridded surface data (1000mb height, temperature, and dewpoint) if such information is available.

3. Reanalysis of CLDOP8

CLDOP8 is a functioning algorithm for the simultaneous estimation of cloud optical depth and effective particle radius. The current algorithm uses radiance in two or three spectral bands. The 0.75 and 2.16 μm bands are always used and the 3.70 μm band can be used. The third channel is required to resolve an ambiguity in effective radius for clouds with optical depth less than approximately four. The algorithm will be applied to daytime data only.

Additional information was obtained from Dr. King and other members of the atmospheric group during the February MODIS Science Team Meeting. It is now expected that four bands will be used at all times and that the processing will only be done for a single (or a few) pixels in each 25 square kilometer area. Both of these factors are included in the estimate (one pixel assumed).

The algorithm uses a large look-up table for the reflectance function. This is done to avoid doing radiative transfer calculations as part of this algorithm. The table contains the reflectance function as a function of 3 wavelengths, 9 particle radii, 39 solar zenith angles, 26 satellite nadir angles, 33 sun satellite azimuth angles, and 4 optical thicknesses. The setup of the algorithm requires approximately 400 floating operations (FLOP) plus 2,500,000 data reads. As currently implemented, the algorithm requires approximately 15 MBytes of memory.

This is a large storage requirement. However, with this data in memory the solution can be done for many observations. The only additional data required for each solution are the two or three radiance values and the angles.

The bulk of the computations are contained within two nested DO loops which run over the 9 radii and the 2 or 3 wavelengths. A logical IF is used so that some of the calculations are done only for the 0.75 μm wavelength. There are additional logical tests contained inside the DO loop which branch the program on the magnitude of the optical depth and other parameters. This estimate assumes that the path requiring the most computation has been taken and hence is a maximum estimate. (That this is probably not a large overestimate is shown by the comparison with the runtime data.)

The processing requirement for the method was estimated at 32,000 (41,000) FLOP for 2 (3) input wavelengths. It is difficult to estimate the fraction of the pixels to which this algorithm will be applied. The two wavelength method can only be applied for optical depth larger than approximately 4. The three wavelength method may be applied if the optical depth is in the range 14. It is now assumed that the four channel method will be used for all data and will require approximately 50,000 FLOP per pixel.

We have obtained a run-time estimate for this algorithms from D. T. Nakajima who developed the code while working with Dr. King.

Dr. Nakajima estimates that 0.02 sec is required for the calculation part of the processing on the IBM 3081 with the maximum optimization applied. For the 3081 and maximum optimization, the actual performance is estimated at 1.4 MFLOPS. This corresponds 28,000 FLOP pixel which is in excellent agreement with the above estimate.

It is possible to use a single equation to estimate the processing requirement. The result is:

P = { # * % * 50,000 }/A

where:
- # = number of fields of view per second
- % = fraction of pixels with cloud cover
- A = number of pixels in the resolution cell

If the assumption is made that %=0.5 and with #=12,000 and A=25, then P=12 MFLOPS, or **a daytime processing requirement of about 12 MFLOP per scan.** This is a big number which is only appropriate for daytime data. There are a moderately large number of operations done on a significant fraction of all pixels. The number of operations per scan is the above number divided by 1.02 and multiplied by 0.40 as the factor for daylight. The result is approximately 5 MFLOPS.

This processing will generate three cloud products: Cloud Optical Thickness, Cloud Droplet Effective Radius, and Cloud Water Thermodynamic Phase. The phase calculation has not been explicitly sized. It is clearly not significant since this can be determined rather simply by taking the ratio of NIR radiances.

Level-2 to Level-3 Sea Surface Temperatures (SST)

The Science Team Members (STM) will determine the actual characteristics of the SST products. They will determine the actual grid sizes (which will vary between 1, 4, 20, and 50 km), the weighing factors (in space and time) for compositing the SST observations, and the analysis periods for each product. The estimate which follows is based on reasonable assumptions, but it does not claim to be the method that the products will ultimately be prepared.

1. Begin Time Compositing

The SST observations (856 meters nadir IFOV) which will be used to produce the Level-3 products from the Level-2 data. They are the inputs to this product. These inputs will be objectively analyzed to form SST fields at regular grid points with fixed grid sizes (1 ,4, and 20 kilometers). This permits charts to be produced (with contours, if required). The same analysis technique is used at all grid scales and for both compositing intervals (24 hours, 7 days, and monthly). The analysis is a weighted average procedure. The closer the observation is to the grid point the higher its weight Recent observations have a higher weight than older observations. The pixels must be rectified because in their size difference toward the scan ends.

If there were no observations in that grid for the analysis period, the weight of the grid point value is halved. It is then saved for use during the next analysis period.

Grid point values (at the center of the grid) are updated before each product is generated. The updated grid point value is calculated from the weighted average of all the observations which occurred in each individual grid during the analysis period. They are weighed based on their distance from the grid point location and linearly with their age. A weighed average characteristic is that it may be done sequentially as the observations occur. The final value nay be calculated by using each observation as it is located in the grid. This equalizes the computational requirement over the analysis period. (A familiar example which illustrates this is the reader's quality point average (QPA) in college. The same numerical result is obtained if a QPA is calculated at each semester's end instead of waiting four years to do the computation.)

In 24 hours, a 1 kilometer grid near the equator may not have any new observations while one in the Arctic may have two or three new observations in it during daytime. Nighttime SSTs will be intermingled with daytime SST observations. This occurs because the descending nodes will cover the area gaps between ascending nodes.

2. Defining the Grid Arrays

Latitude and longitude boundaries are defined for a rectangular area. All Level-2 SST observations since the last analysis within the grid are used. The grid sizes are 1 kilometer for local daily products, 4 kilometers for weekly regional products, and 20 and 50 kilometers for global weekly and monthly products.

It is easy to calculate an estimate for the number of grid points required. The surface area of the earth is $4\pi\ 6{,}371^2 = 5.1 \times 10^8$ km^2. Assuming that 10% of the surface area of the Earth is water less than 1,000 meters deep, 5×10^7 km^2 is a reasonable estimate for the number of 1 kilometer grid points required for SST local products. Approximately 14% of the Earth surface area is composed of mediterranean and adjacent seas (7.17×10^7 km^2). Twenty percent will be a generous estimate for 4 kilometer weekly regional products. This is about 4.5×10^6 four kilometer grid points. The regional and the local products are assumed to overlap. Hence, the remaining part of the Earth's oceans (3.6×10^8 km^2 - 7.2×10^7 km^2 = 2.9×10^8 km^2) could be covered with 20 kilometer square grids (which are updated monthly). There are about 720,000, 20 kilometer squares (2.9×10^8 km^2 / 400 km^2) grids which comprise the remainder of the Earth's oceans. The total number of grid points required with their updating frequency is listed in Table 1

Table 1: The number of grid points required for SST calculations.

Size and number of grid points		Update Frequency
1 kilometer^2	5×10^7	daily
16 kilometer^2	4.5×10^6	weekly
400 kilometer^2	720,000	monthly

The total number of grid points for which weighed values must be computed is the sum of the numbers in the table. This is about 5.5×10^7 grid points. It is apparent that the 1 kilometer products are the driver.

3. Putting the Level-2 Observation into the array (on-the-fly)

Only the 1 kilometer array operations will be discussed since the number of operations required to do this is much larger than for the 4 kilometer or 20 kilometer arrays.

It is possible that three separate arrays will be created (1 kilometer array with 5×10^7 elements, a 4 kilometer array with 4.5×10^6, and a 20 kilometer with 720,000 elements). These arrays will make it easier to reset the weights for cloudy pixels.

Each Level-2 observation must be placed in an appropriate array (there will be overlaps); i.e., 4 kilometer grids will overlay some 1 kilometer grids, and 20 kilometer grids may overlay both 1 kilometer and 4 kilometer grids.

The center point of each grid will have a latitude and longitude which may be considered as the coordinates of a two dimensional array.

Because MODIS-N has 12,656 pixels per scan and 86,164/1.02 scans per day, there are a maximum of 1.1×10^9 Level-2 SST observations which must be placed in the arrays each day. Cloudy pixels will reduce this number by 50% (or more with a conservative cloud filter, up to perhaps 75 to 80%) on the average.

Each pixel will have a latitude and longitude. The latitude and longitude value will be used to associate the observation with the proper array element; i.e., the observation's latitude will be changed into an array's index value. The procedure for latitude is explained (longitude should be identical).

A relatively simple procedure will do this. The steps are listed below.

1. Divide the decimal latitude value by the scale interval.
2. Compute the remainder (using mods).
3. If the remainder is less than .5 drop it. If the remainder is greater than .5 add 1 unit. This gives the exact grid point value.

Assume that N represents the number of observations which occurred in the grid during the analysis period;i.e. it is the number of observations to be weighed per analysis period. N can range from zero to 10. A representative value ranges from 1 to 5.

Operation	Steps
Change latitude value into "i" array value	12N
Change latitude value into "j" array value	12N
Subtotal $24N \times 5 \times 10^7$ =	$120N \times 10^7$

The subtotal value represents the number of opeations per day.

4. Calculating the Weighed SST Average (At a Grid Point)

The weighed average for all the SST observations in the search area is calculated based upon the square of the distance from the grid point center (based on AVHRR procedures). A weight is assigned to the pixel based on its location in the scan. It is not clear what this weighing factor should be, but it will be based on the pixel size and its distance from the nadir point.

After weighing the observations, the existing SST grid point temperature is replaced by a weighed average of it and the weighed average of the observations calculated previously.

If no new measurements are observed in a grid point, during the analysis period (due primarily to clouds), the exiting grid point temperature is retained and its weight halved (for use during the next update).

The distance of the observed value from the grid point is calculated using a formula for the distance between two points on the earth.

Weighing Calculations

Calculate distance between two points on the globe

Operation	Step
Distance calculation	15N
Assign weight to each observation	N

Compute Weighted average (sum of the weights X temperatures divided by total value)

Multiply temperature X weight	N
Sum of temperature X weights	N - 1
Divide by total value	N

Total number of steps for weighing based on distance
$(19N - 1) \times 5 \times 10^7 = (95N - 5) \times 10^7$
The subtotal value represents the number of opeations per day.

Pixel rectification

Read pixel scan number	N
Read pixel weight from look-up table	N

Total number of steps based for weighing based on pixel location in the scan $2N \times 5 \times 10^7 =$ $10N \times 10^7$

Time Weighing

The weigh of the SST value is changed if no new observation have occurred in the grid because of clouds during the analysis period. AVHRR halves the weight for each observation period.

Change weight of all points at the end of the analysis period N (This will get all the cloudy pixels)

Total number of steps to weighing cloudy pixels with no new observations $N \times 5 \times 10^7 =$ $5N \times 10^7$

Compute grid point Temperature (by combining weights)

Combining weighed temperatures 4N
Subtotal $4N \times 5 \times 10^7 =$ $20N \times 10^7$
The subtotal value represents the number of opeations per day.

5. **Total number of steps required**

The total number of steps required is all of the subtotals summed:

$120N+95N-5+10N+5N+20N \times 10^7 = \quad (250N - 5) \times 10^7$

If N = 3, the total number of operations required per day is 7.5×10^9. **This is about .1 MFLOP per scan.**

The current estimate is very preliminary. A more careful study is required to determine how much CPU time (execution time) versus I/O time is required to run an algorithm. Once this is done CPU resource requirements can be re-evaluated for a better estimate.

MODIS PACKETIZATION CONSIDERATIONS

1. Background

MODIS data may be packetized in either band-sorted or band-interleaved forms. Band sorting permits many observations of only one spectral band in a packet (30 x 22 for MODIS-T). Band interleaving includes a moderate number of observations from all bands in a packet (32 x 21 for MODIS-T).

The band sorted packets are more amenable to manipulation (i.e., decommutation of all data is not required) when special processing is performed (e.g., direct broadcast, near-real-time, quick-look). The band sorted packet method is more sensitive to randomly lost or bad packets, as multiple bands are required for geophysical products.

An optimal packetization method should be determined.

2. Considerations

- Relative Sensitivity of Geophysical Products to Packet Loss
- Relative Ease of Handling of the Data
- The Precise Definition of a Bit Error
- The Number of Lost Packets
- The Number of Damaged Packets

Orbital Period	98.88	minutes
Ground Velocity	6.75	km/sec
33 km Scan Period	4.89	seconds
# of detectors	30	x 1,007
# spectral det	32	
# Obs per second	1.98E+05	
# Obs per orbit	4.69E+08	
# bits per ob	12	
Fraction daylight	40%	
# bits per orbit	5.63E+09	
# bits per day	8.20E+10	
Bit error rate	1.00E-08	
# bit errors	819.69	
# errors in packet	16	
# bad packets per day	52	
# bits in packet	8000	
# obs in packet	667	
# bands in algor	8	
Fraction bands req	25%	
# bad packets per day	13	
Fraction Ocean	70%	
Fraction cloudy	50%	
# bad packets per day	5	